Nuclear Modification of B-mesons in Cu+Au collisions at 200 GeV Measured Through B->J/ψ decay by the PHENIX Experiment

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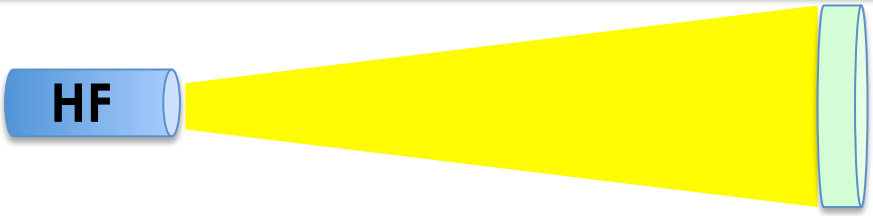
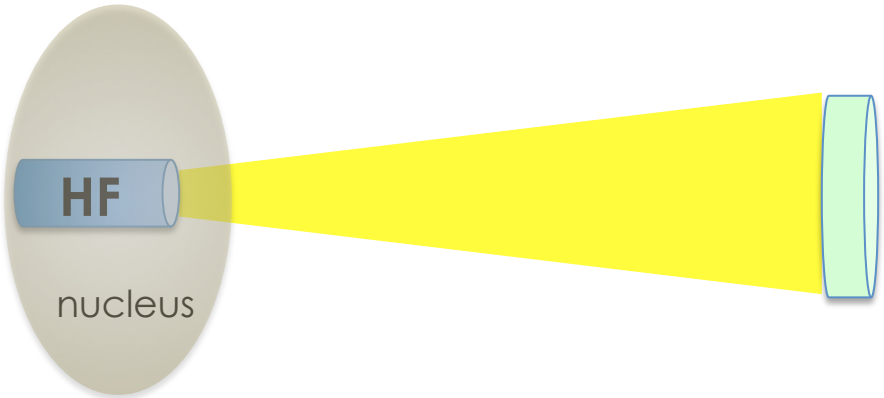
Quark Matter 2017, Chicago

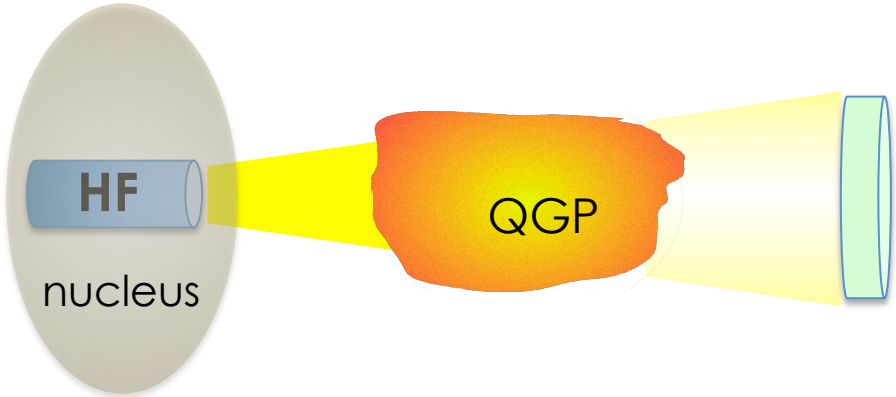
What is needed to probe QGP property with b-quarks



PRODUCTION



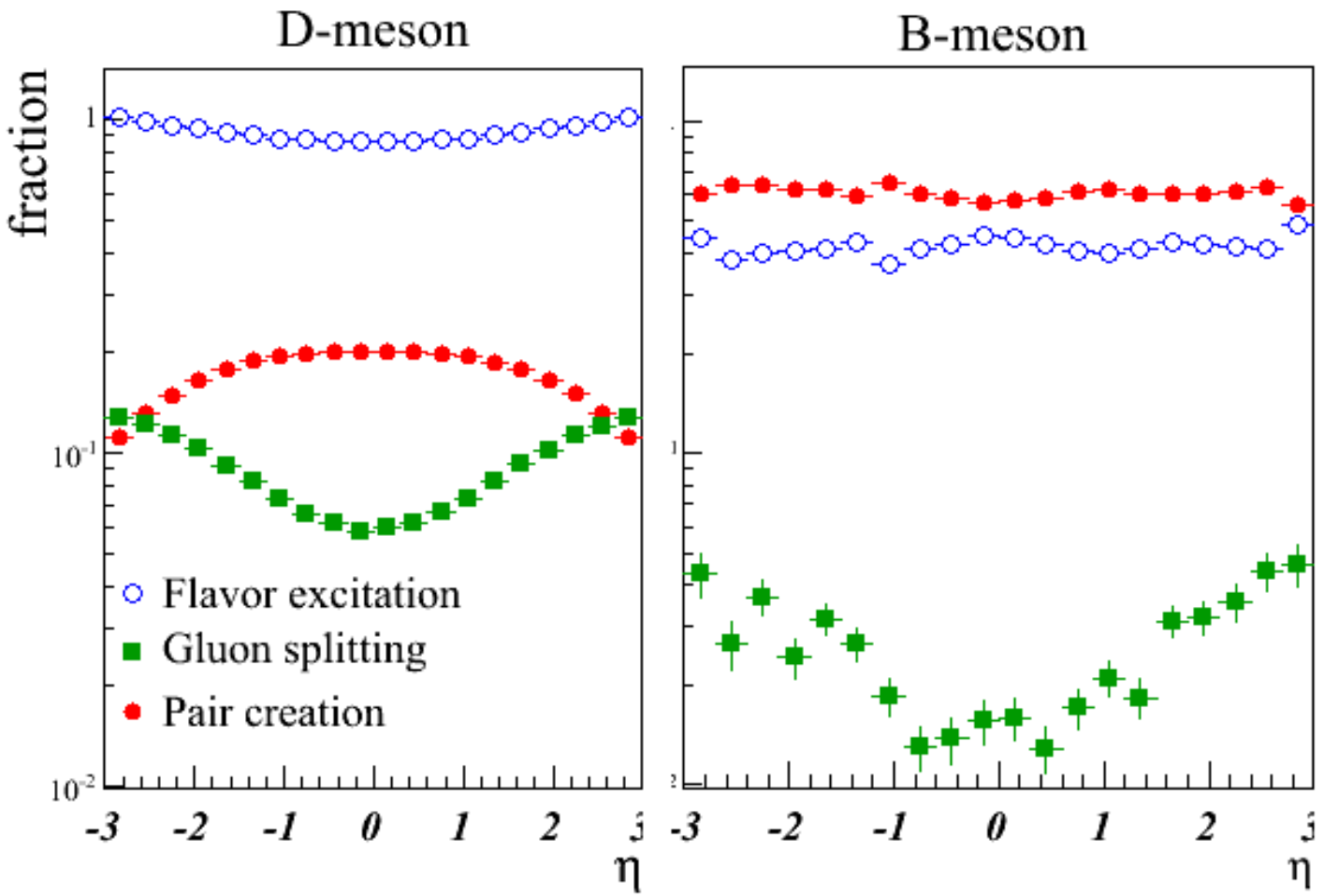
INITIAL STATE EFFECTS

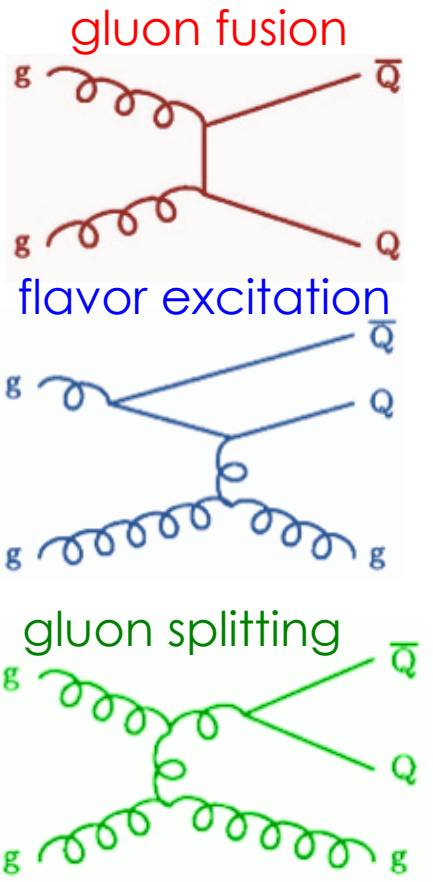


FINAL STATE ENERGY LOSS, DIFFUSION …

Heavy Flavor production at RHIC

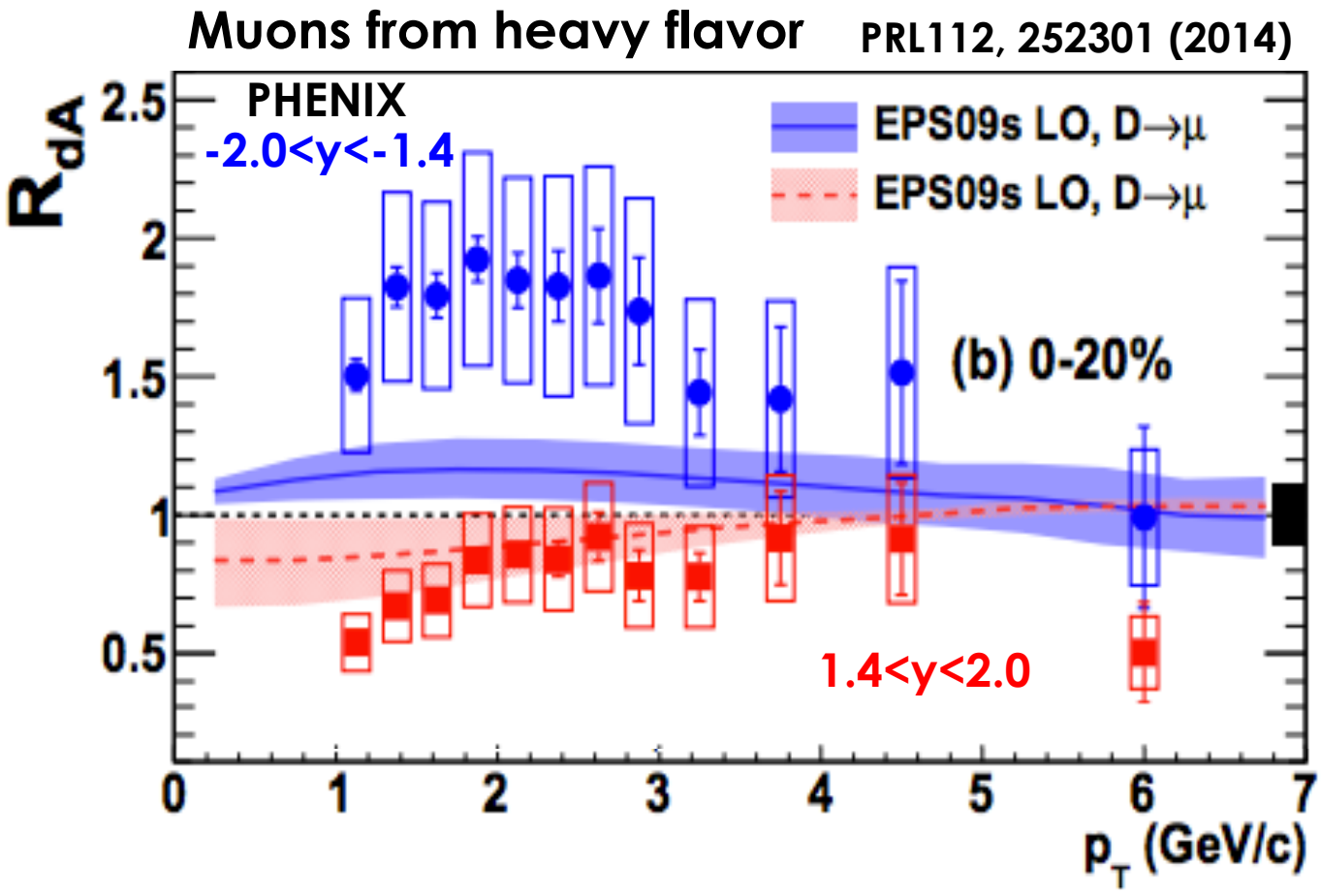
PYTHIA6 hard scattering @ 200 GeV





Contrast with LHC where gluon splitting dominates heavy flavor production.

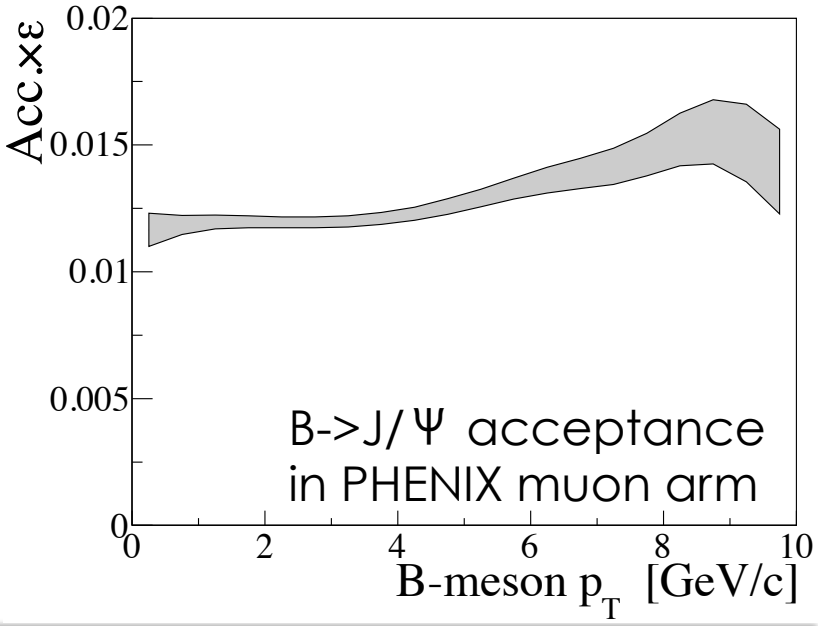
Initial state effects on heavy flavor



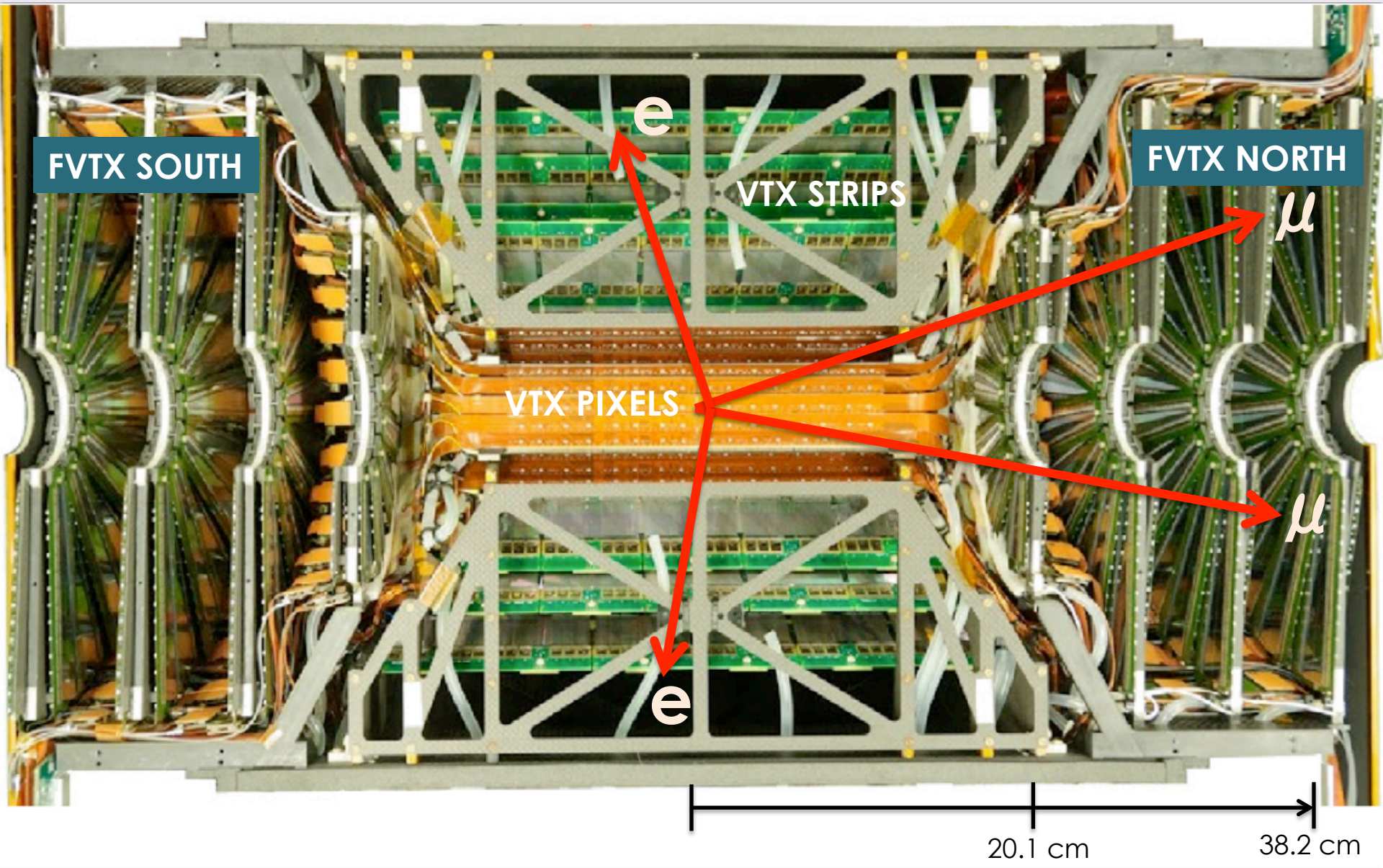
Initial state effects on gluons can suppress and enhance yields as observed in d+Au.

Probing Initial State Effects in AB collisions

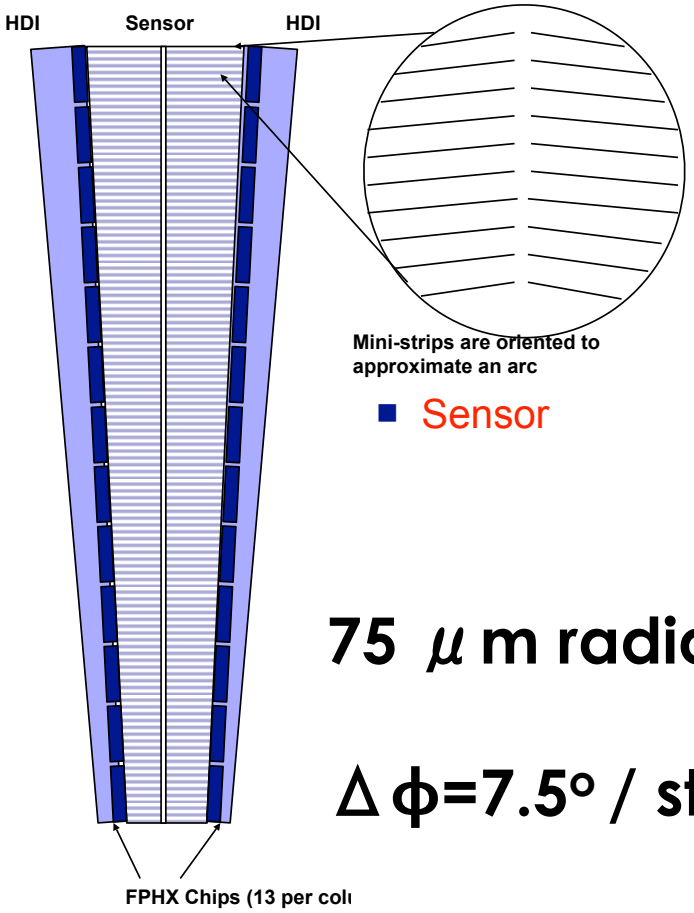
- Heavy quark number is preserved in strong interactions
- total heavy quark yield depends only on initial state effects on gluons
- Final state energy loss in the medium modifies only the heavy quark p_T distribution
- B->J/Ψ channel in PHENIX muon arms(1.2<|y|<2.2)
  - Enough boost to distinguish non-prompt J/Ψ even at p_T=0
  - Almost flat p_T acceptance



Vertex Detectors in PHENIX



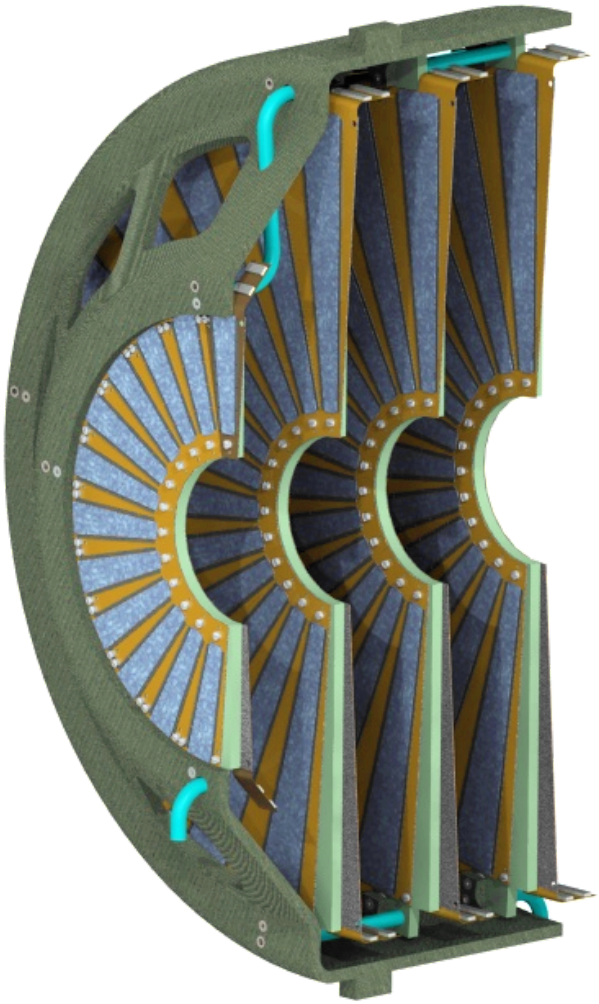
The Forward Vertex Detector (FVTX)



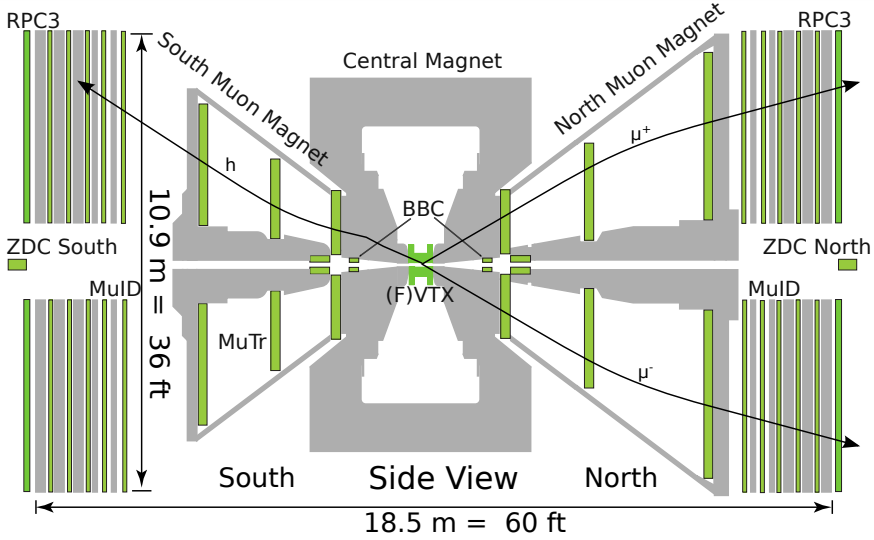
- Sensor

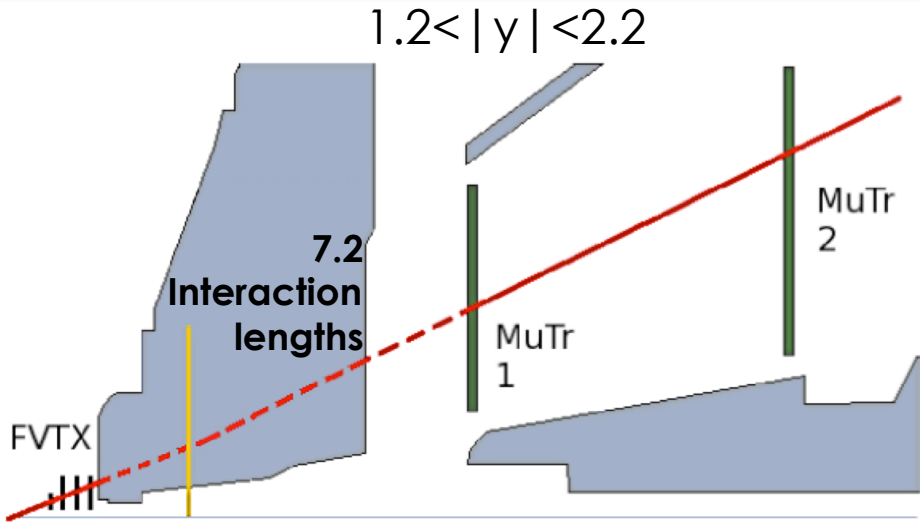
75 μm radial segmentation

$\Delta\phi$=7.5° / strip



Muon Reconstruction



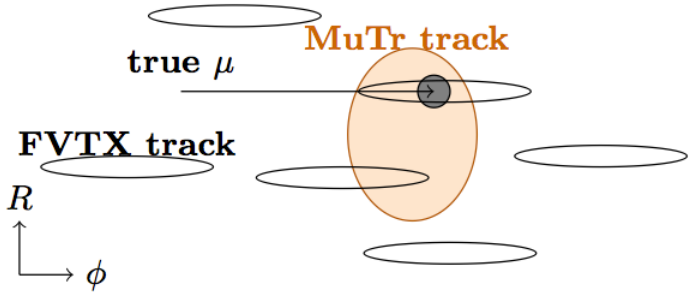


- Full muon track:
  - FVTX track + MuTr+MuID track

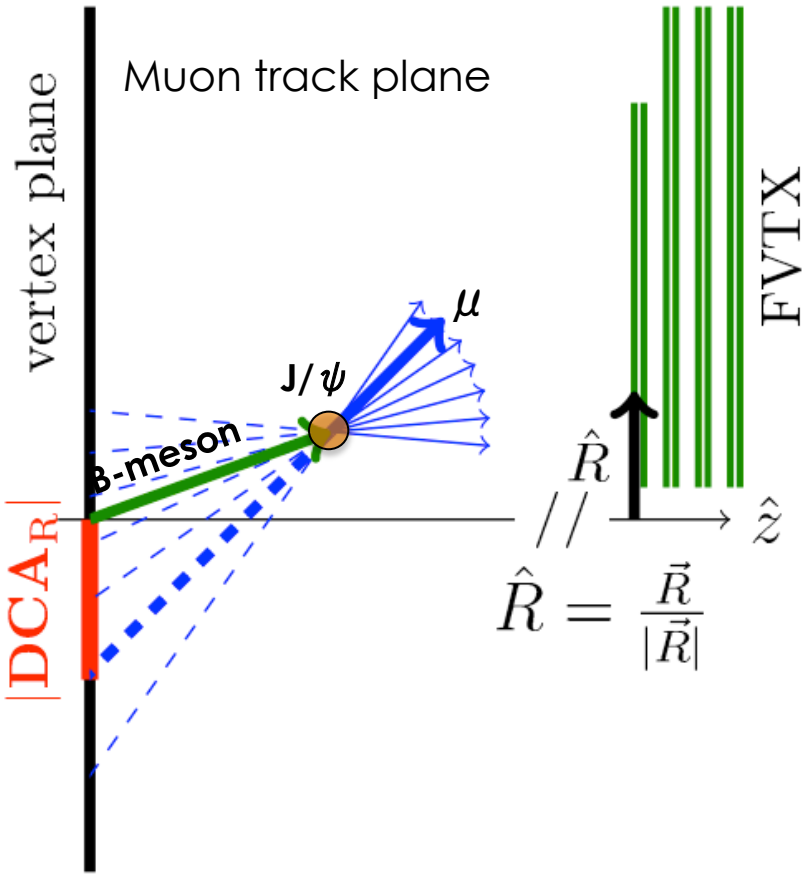
Large projection uncertainty of MuTr track on FVTX planes causing matching with >1 FVTX track

- Keeps all 3σ matchings
- subtract mismatches using event mixing technique

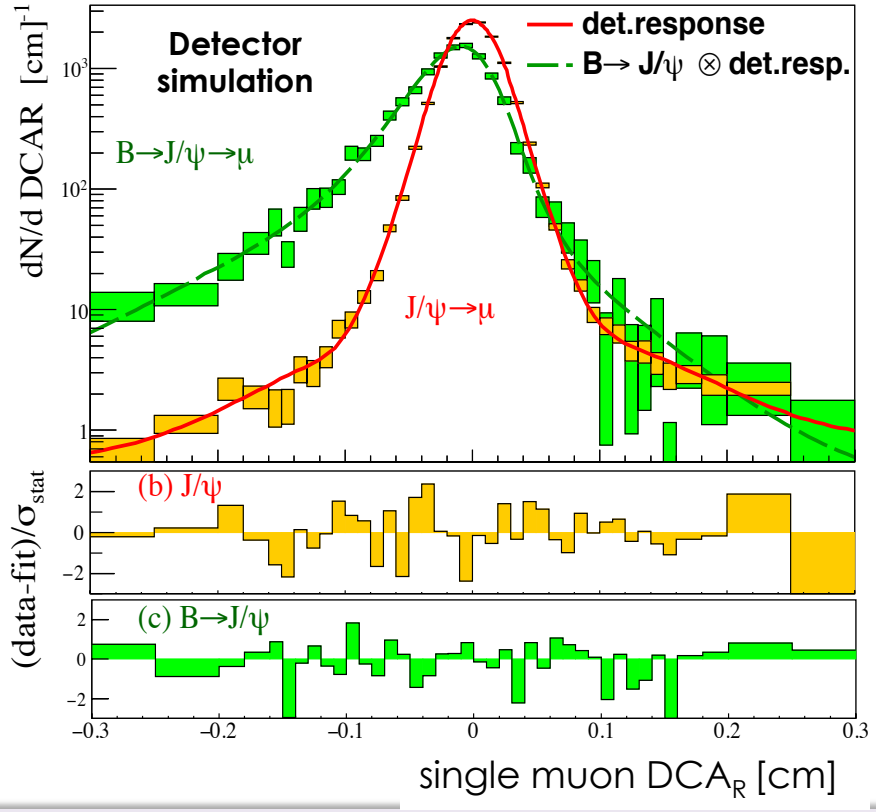
Projections at one of the FVTX planes



Identifying B-meson decays

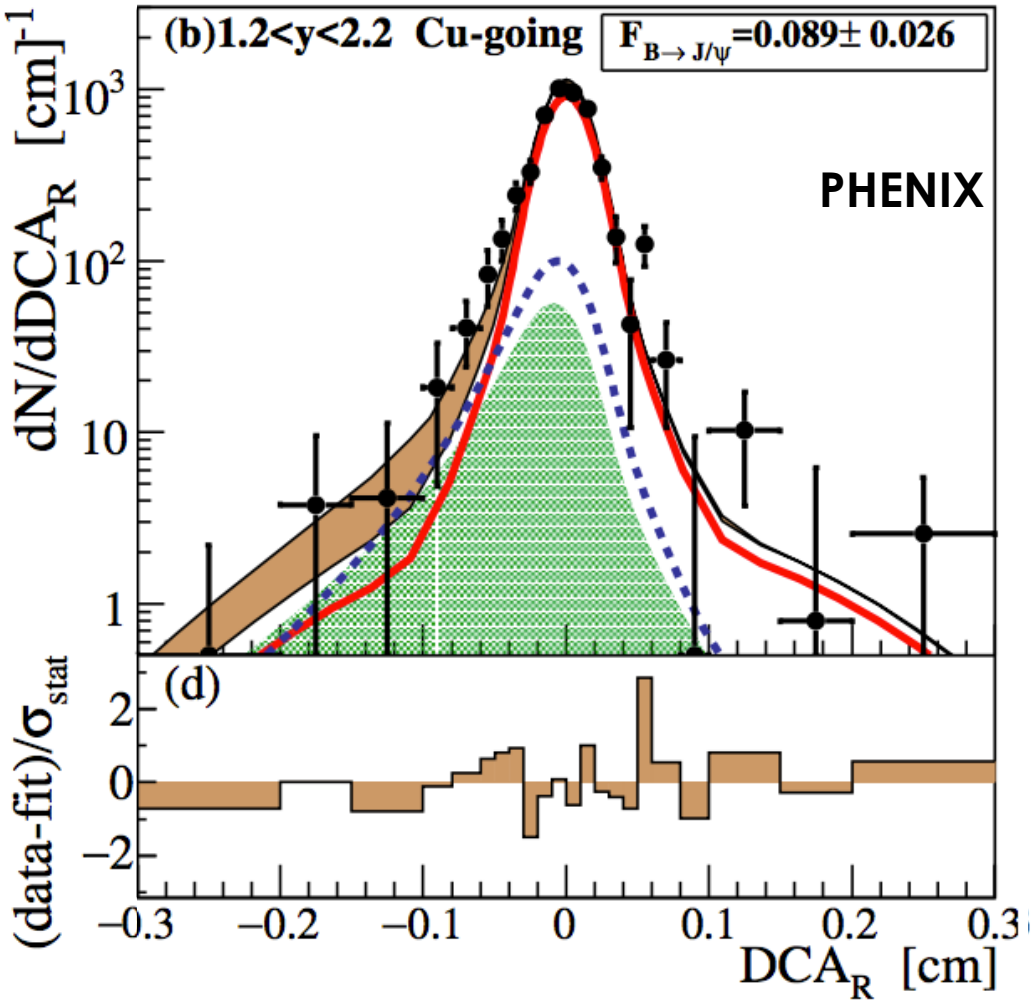


- Decays from long lived particles produce an asymmetric distribution.
- Detector simulation tuned with a large and clean sample of real data prompt pions and kaons reaching the MuID absorbers.



Look for non-prompt muons from dimuons in the J/Ψ mass region.

DCA_R Fits



Integrated Centrality and p_T.

BG from correlated $c\bar{c}$ and $b\bar{b}$ dimuons also produce non-prompt muons.

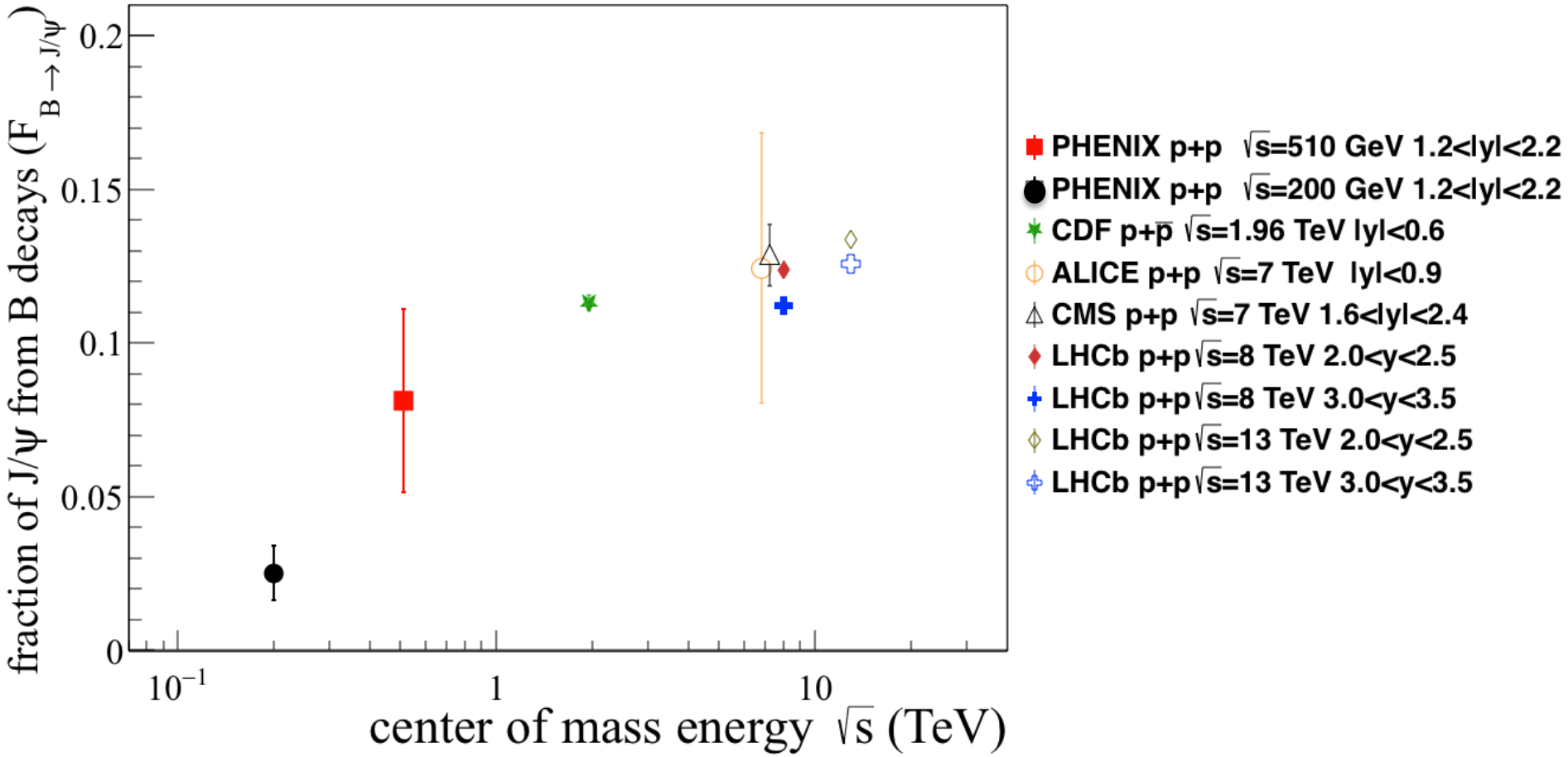
Important systematic uncertainties:

- $c\bar{c}$ and $b\bar{b}$ contribution
- Detector misalignments
- centrality and p_T weighting for simulated DCAR profiles
- Background normalizations

Di-muon combinatorial and FVTX-MuTr mismatch backgrounds not shown for clarity, but considered in the likelihood fit.

$F_{B\to J/\psi}$ results in p+p

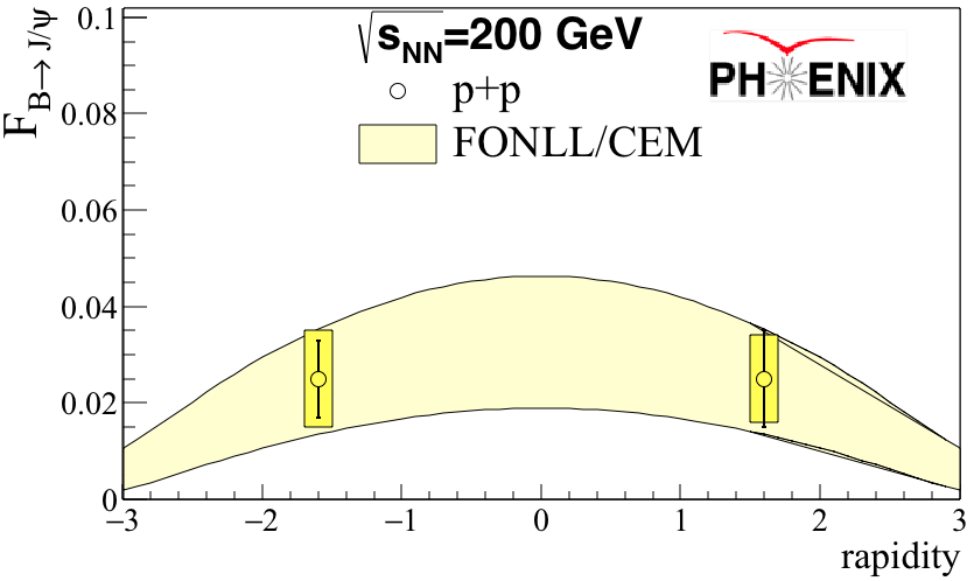
510 GeV result: arXiv 1701.01342
200 GeV result: arXiv 1702.01085

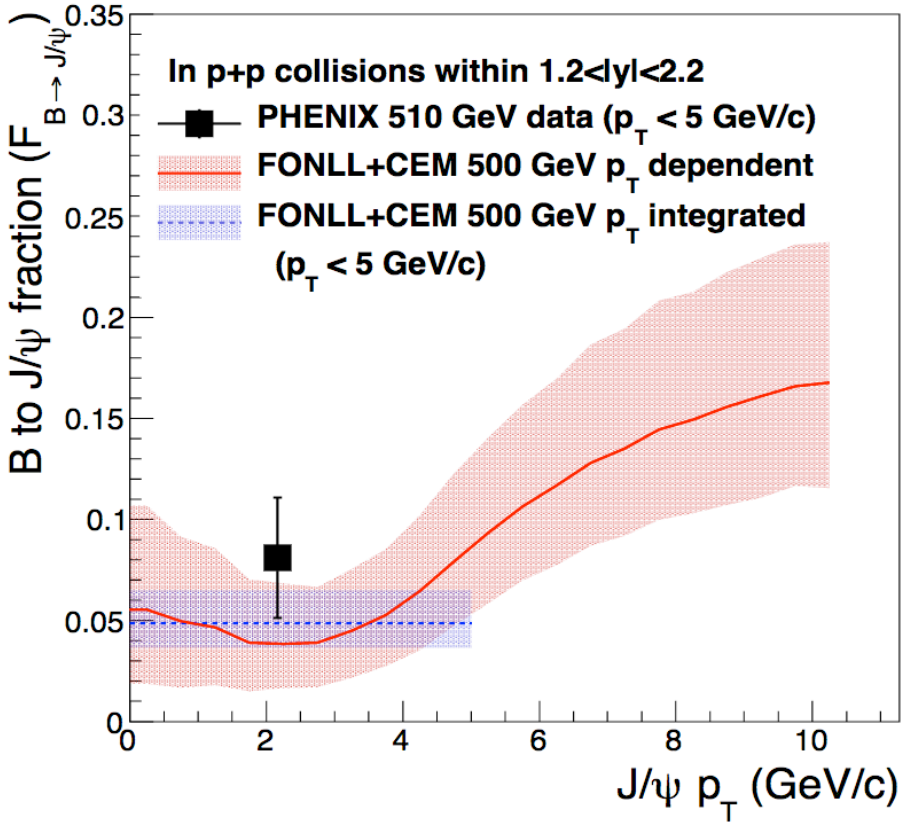


Clear transition from low energy to Tevatron, LHC.

$F_{B\to J/\psi}$ results in p+p

arXiv:1702.01085



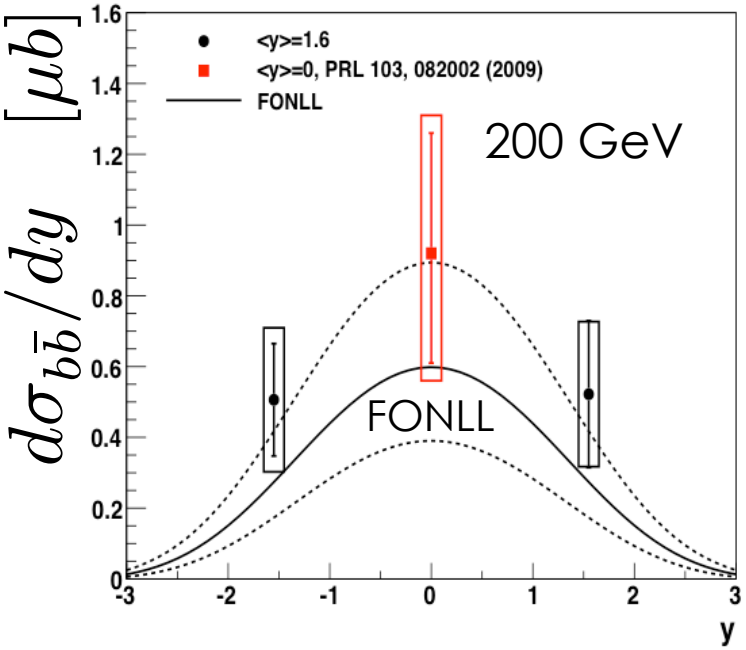


FONLL/(CEM+FONLL) agree with data.

Fixed-order Next to Leading Log (FONLL) [Cacciari, JHEP 05, 007 (1998)]

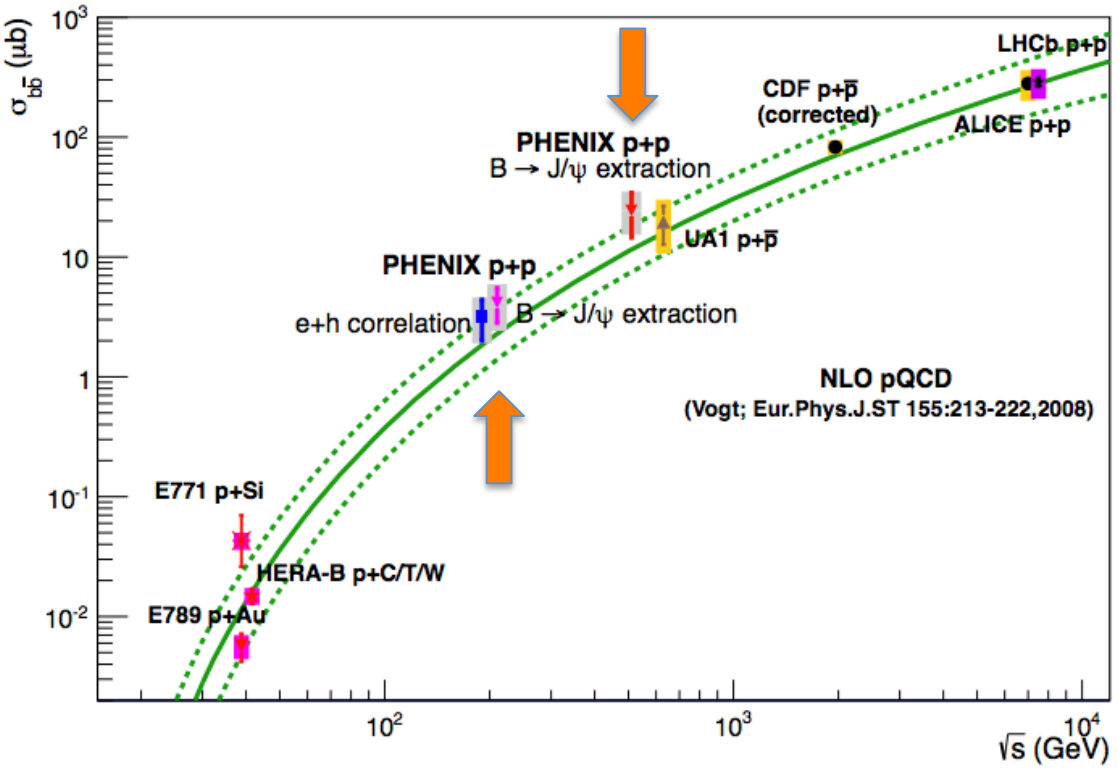
Color Evaporation Model (CEM) [R.Vogt *et. al*, Phys.Rep 462, 125 (2008)]

$b\bar{b}$ cross sections



Using measured J/Ψ cross section and $F_{B->J/\psi}$.

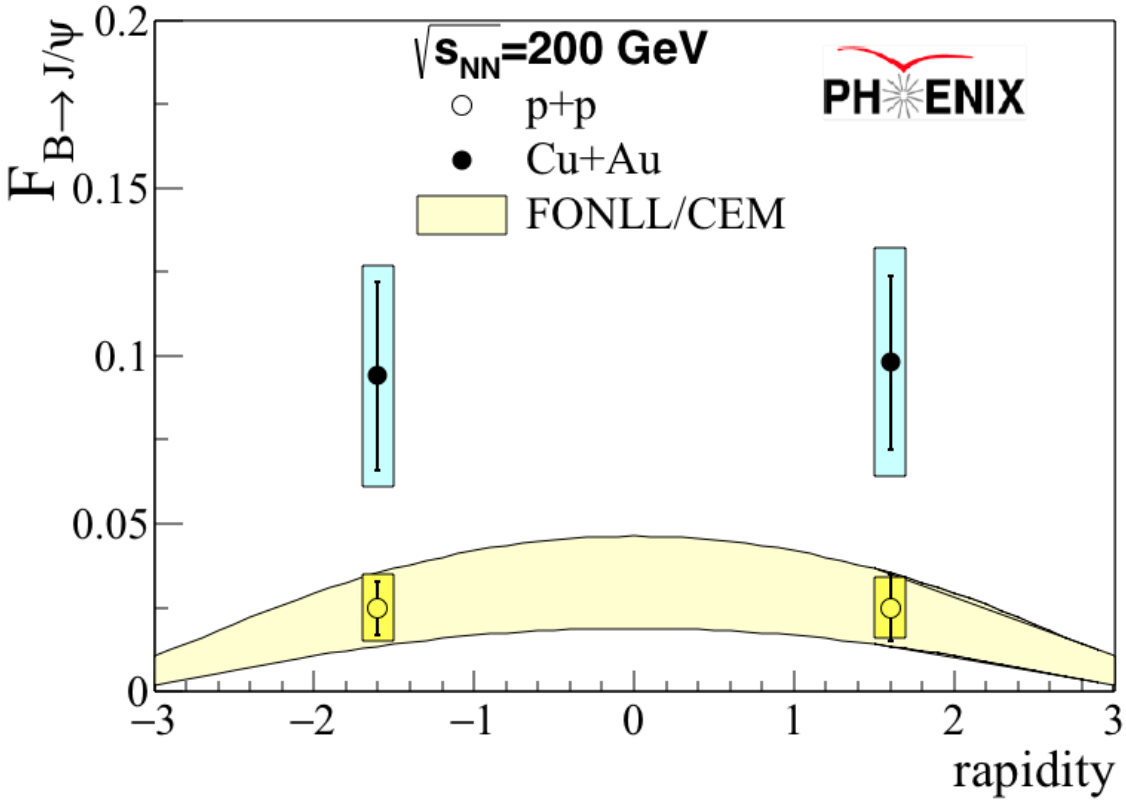
mid-rapidity from e-hadron correlation and PYTHIA extrapolation.



PHENIX measure most of the $b\bar{b}$ cross section.

200 GeV result: arXiv 1702.01085
510 GeV result: arXiv 1701.01342

$F_{B\to J/\psi}$ results in Cu+Au



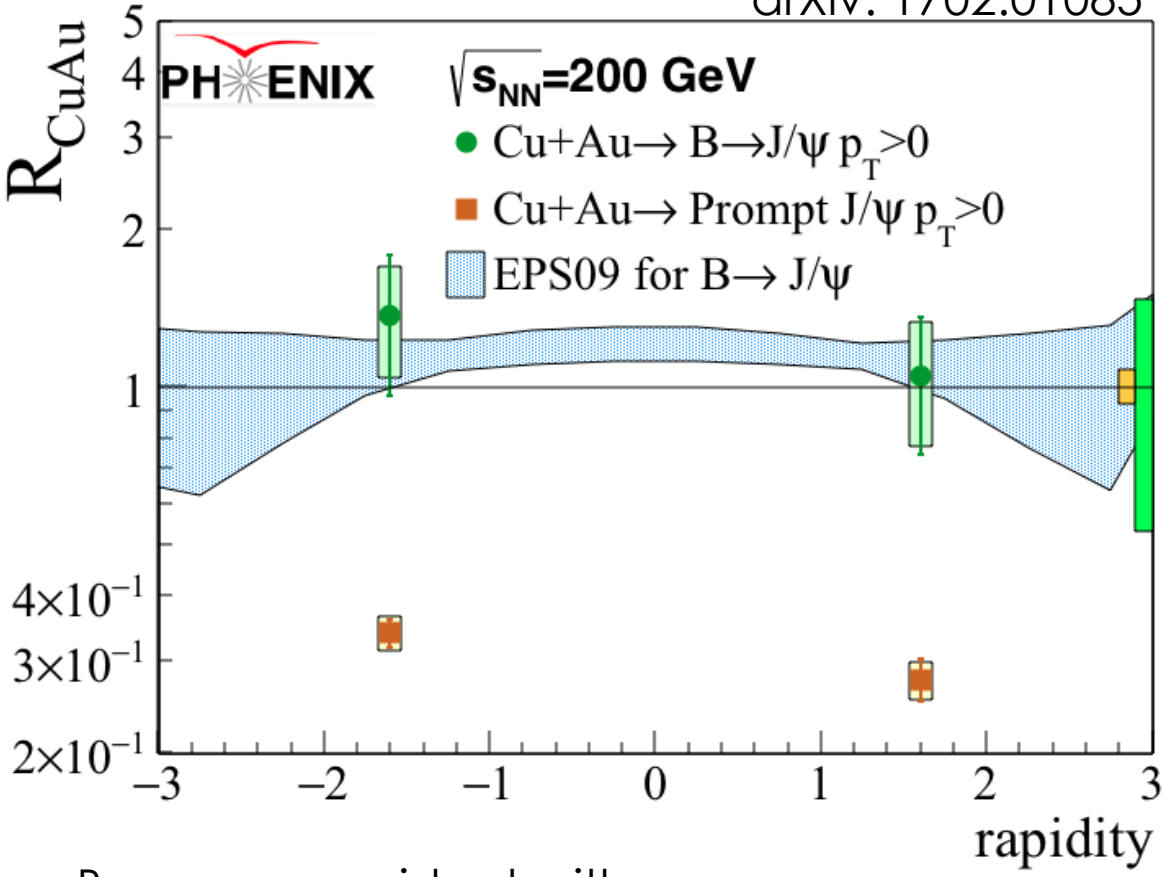
arXiv: 1702.01085

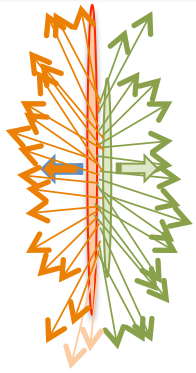
Non-prompt J/Ψ enhanced in Cu+Au collisions relative to p+p.

Reflects that B-mesons are less suppressed than prompt J/Ψ.

B-meson R_{CuAu}

arXiv: 1702.01085





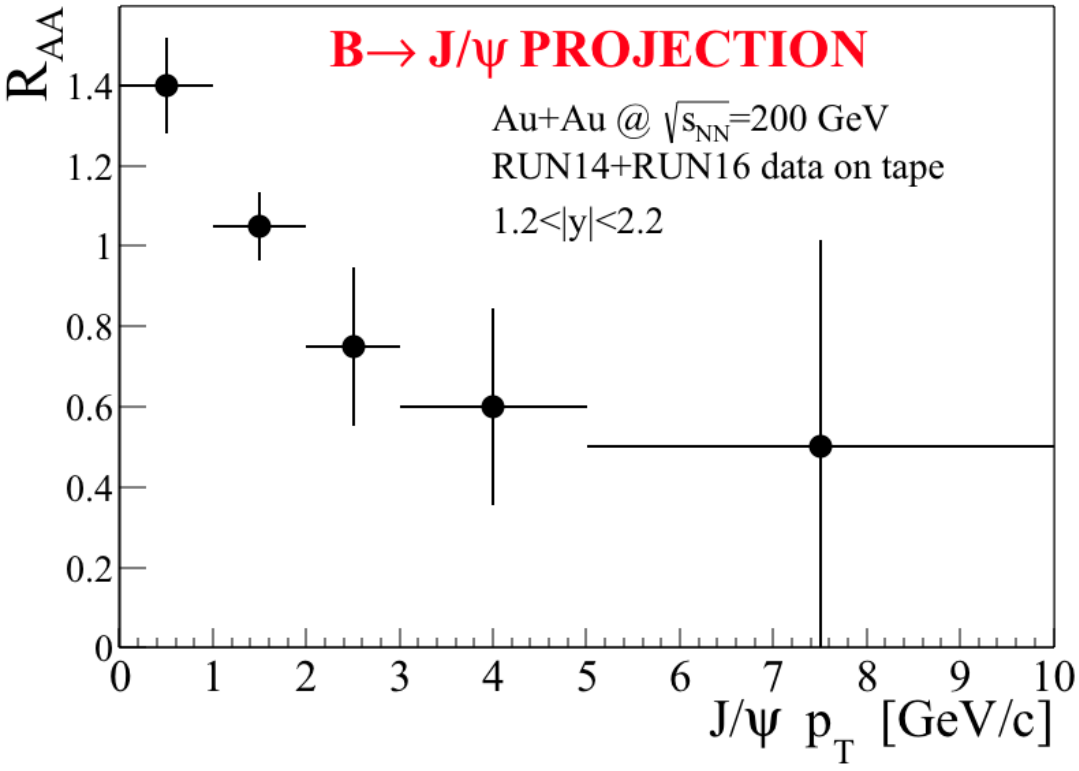
$$R^{B}_{CuAu} = \frac{F^{CuAu}_{B\to J/\psi}}{F^{pp}_{B\to J/\psi}} R^{incl.J/\psi}_{CuAu}$$

$$R^{J/\psi}_{CuAu} = \frac{(1 - F^{CuAu}_{B\to J/\psi})}{(1 - F^{pp}_{B\to J/\psi})} R^{incl.J/\psi}_{CuAu}$$

- B-meson consistent with
  - NO nuclear modification
  - enhancement suggested by EPS09
- Prompt J/Ψ number is not preserved in final interactions:
  - breaking/melting in medium

What's Next

35B events on tape from 2014+2016 Au+Au runs
16x more B->J/Ψ statistics than in Cu+Au



Projection does not include:

- p+p reference uncertainties
- systematic uncertainties

Can use combined data+FONLL as p+p reference.

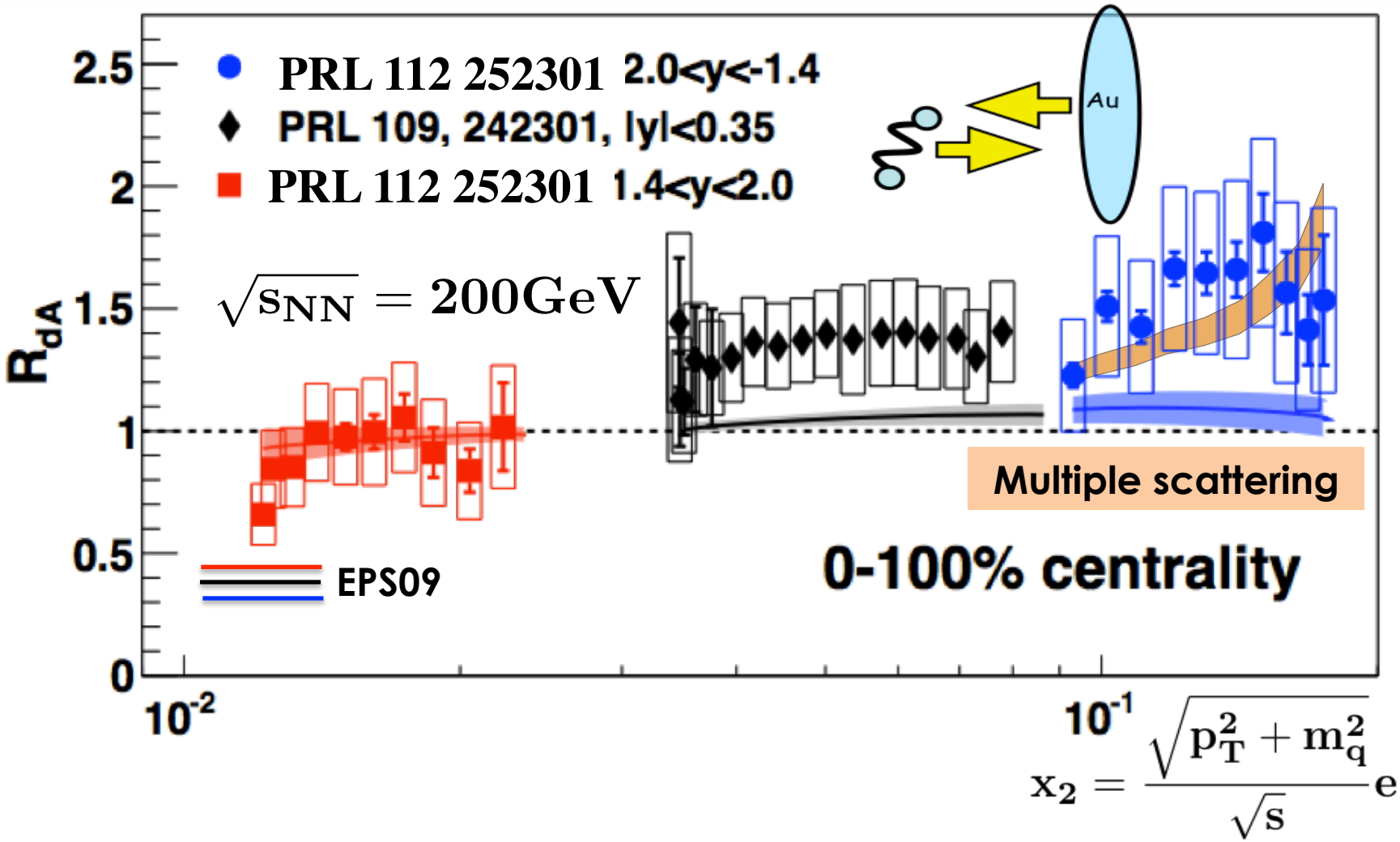
Great opportunity to verify mass hierarchy in initial state effects and final state energy loss.

Summary

- B-meson cross section in p+p consistent with pQCD calculations (FONLL).
- Total B-meson yield in Cu+Au collisions is consistent with binary scaling of p+p yields and nPDF enhancement
- 16x more data to come from 2014 and 2016 Au+Au runs
  - Essential information to understand quark-mass hierarch in the energy loss in QGP

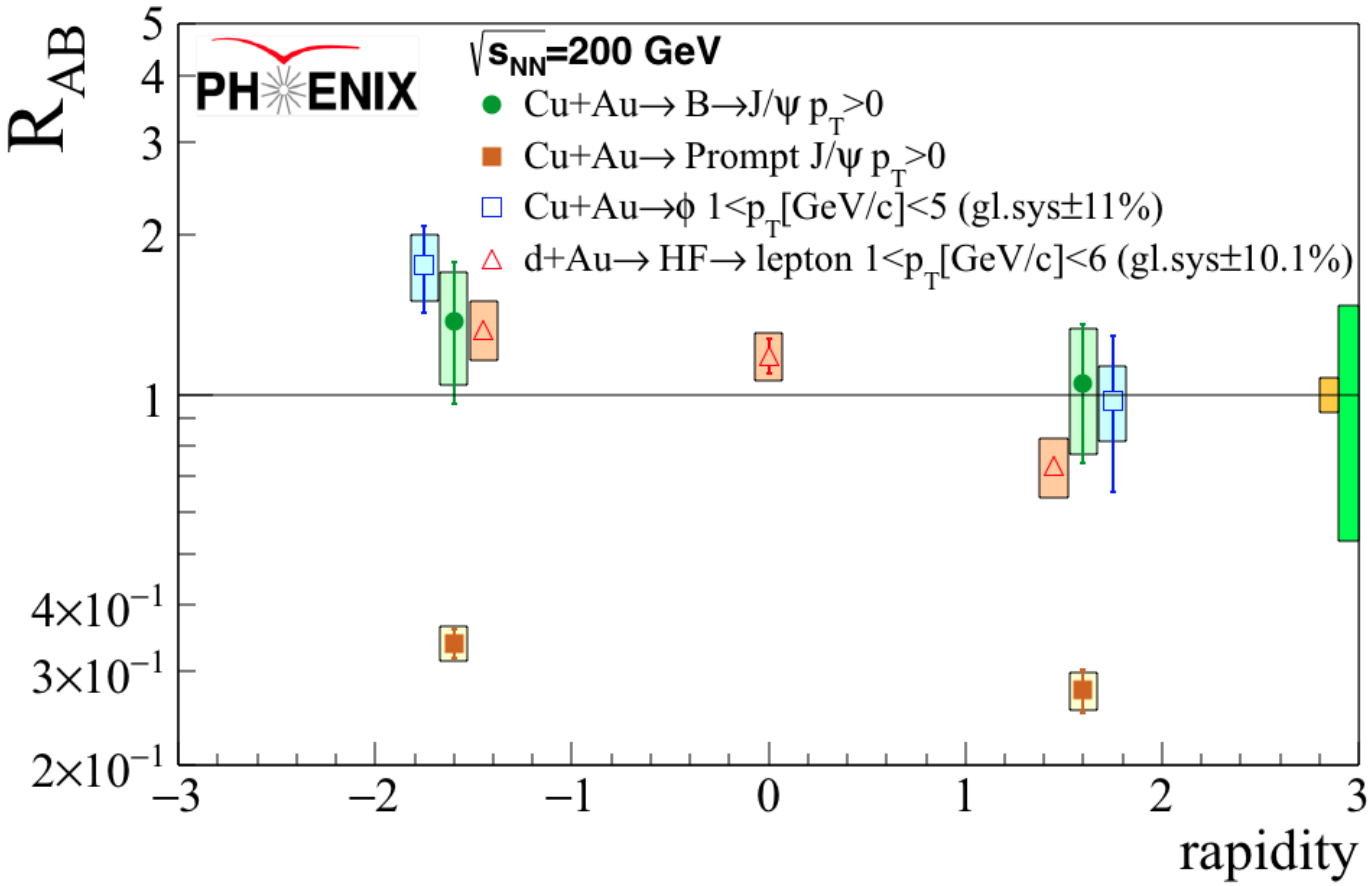
EXTRA

Initial state effects measured in d+Au



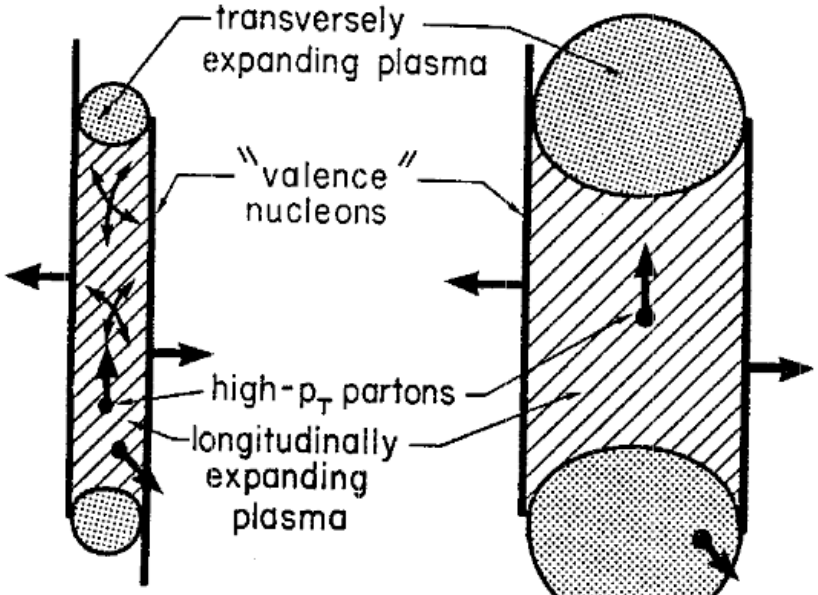
- Current nPDF cannot describe HF at **mid-** and **backward** rapidity (large-x)
- Better agreement with **multiple scattering model [Kang *et al.*, PLB 740, 23(2014)]**.

B-meson R_{CuAu}



- Enhancement trend at negative rapidity also observed in
  - phi-meson in Cu+Au
  - inclusive heavy flavor in d+Au

Partonic energy loss in QGP

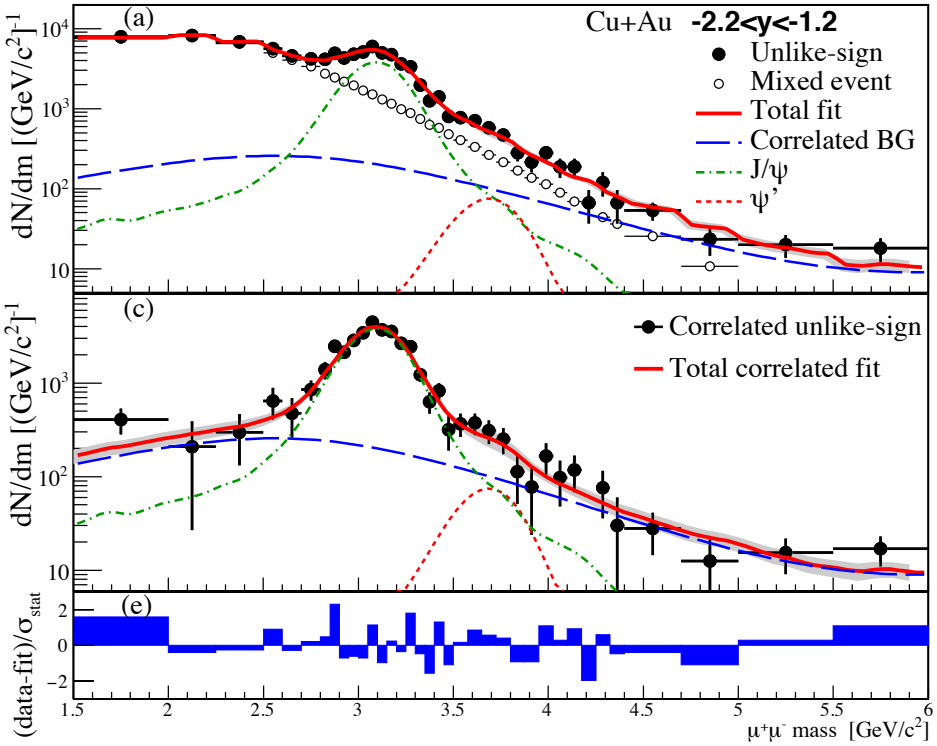


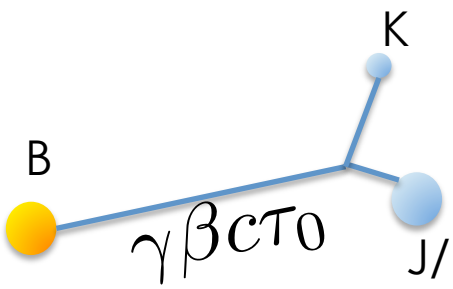
Bjorken (1982)

Energy loss:

- Gluon radiation, elastic collisions
- Gluon radiation suppressed for θ <M/E (dead cone effect)
- Low p_T B-mesons:
  - p_T<<m_b, where quark mass is relevant for energy loss

B-mesons in the PHENIX muon arms

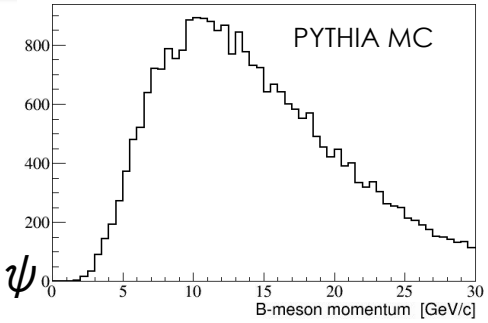


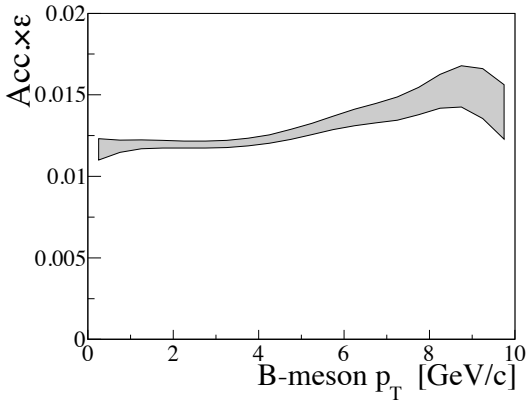


$$\gamma\beta c\tau_0$$

$$c\tau_0 \sim 450\mu m$$

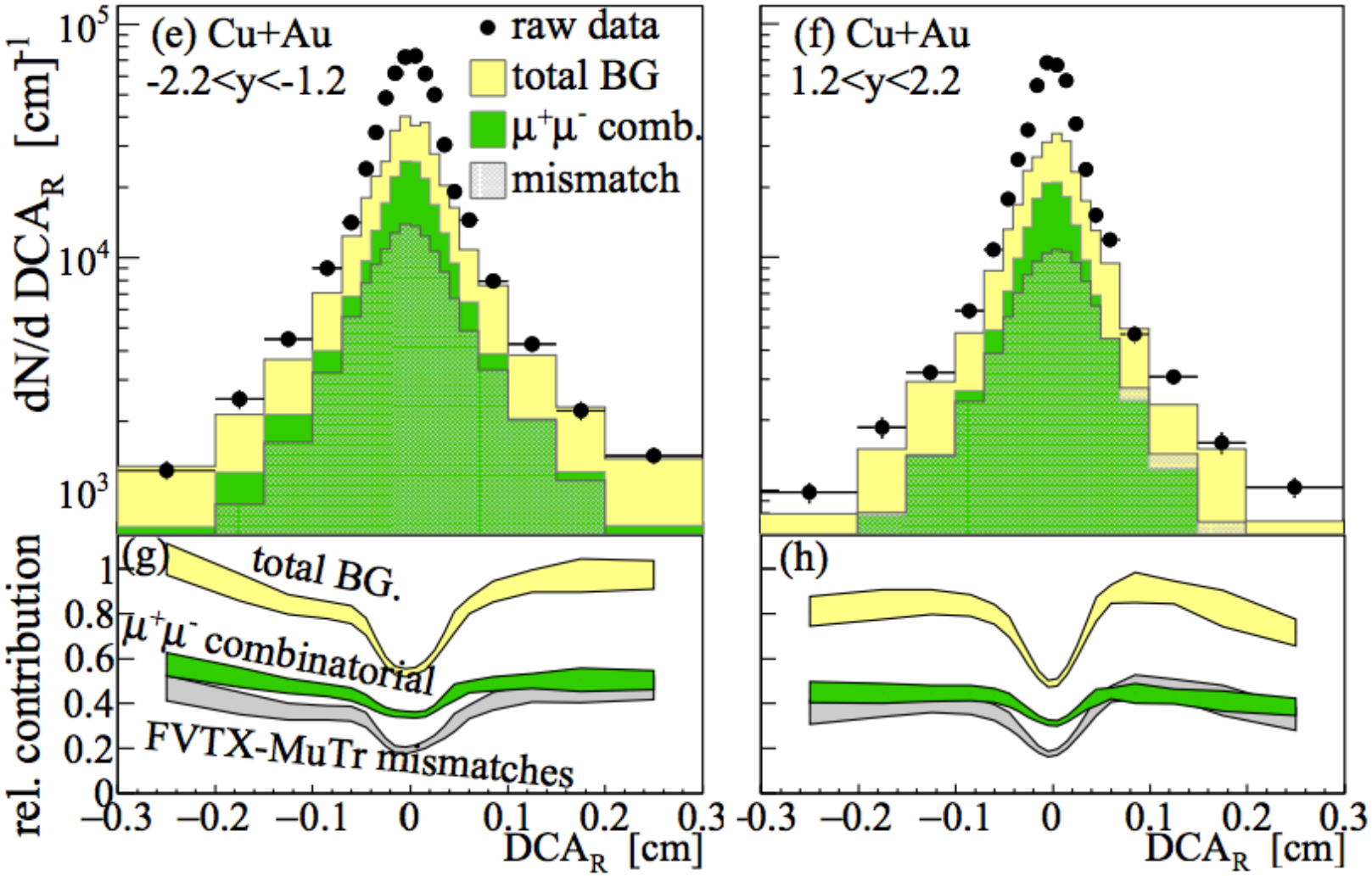
$$\gamma = \frac{\sqrt{p_z^2 + p_T^2 + M^2}}{M}$$





- Decay length is boosted at large rapidities (p_Z>>0) allowing to identify non-prompt particles down to p_T=0
- Flat p_T acceptance for B->J/Ψ

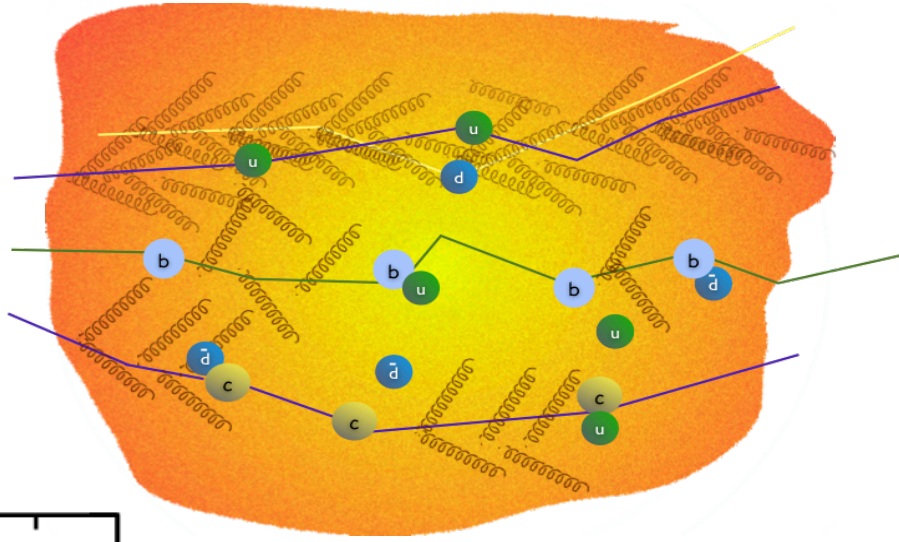
Backgrounds

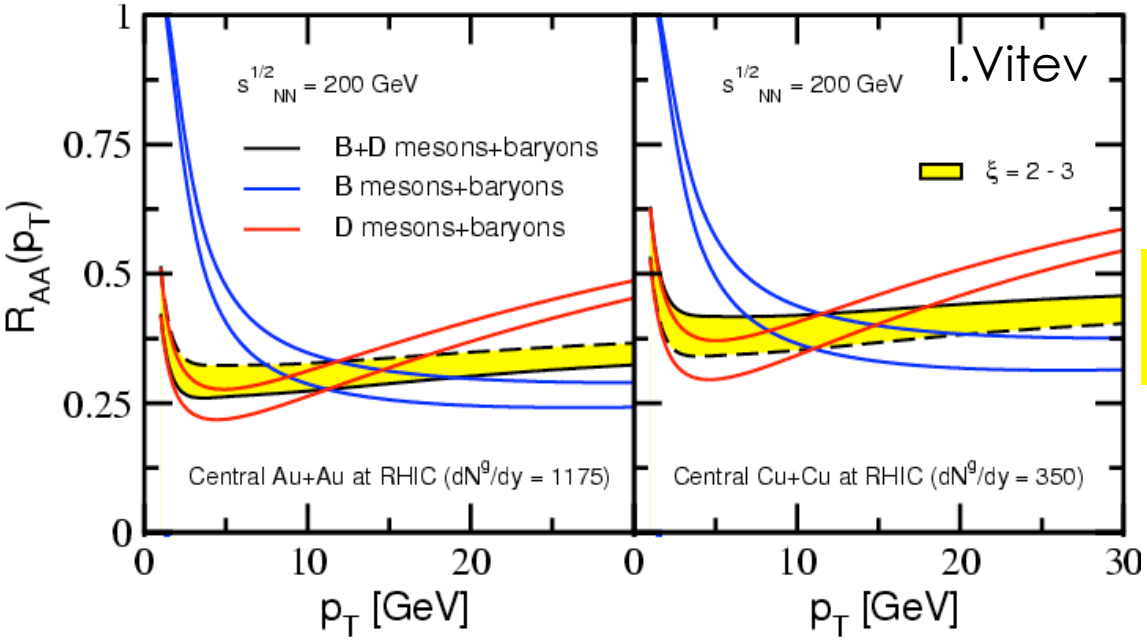


Light, Charm and Bottom Quarks crossing QGP

Energy loss:

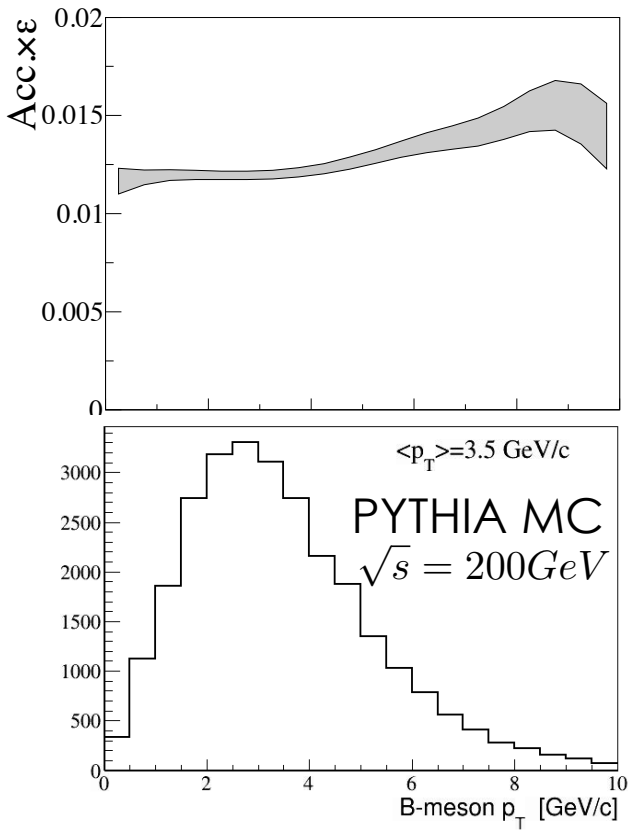
- Gluon radiation
- elastic collisions
- Gluon radiation suppressed for θ <M/E
- Heavy quarks hadronize quickly crossing the medium as mesons or dissociated quarks





Quark mass dependency more pronounced at small p_T

B-mesons Acceptance



$$B \rightarrow J/\psi \rightarrow \mu$$

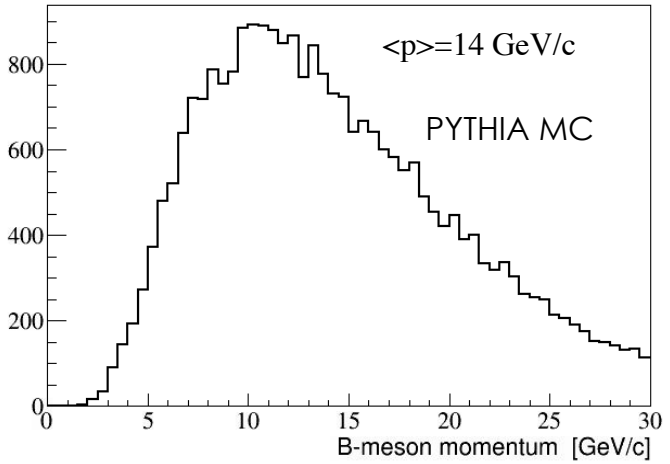
$$R^{\text{prompt}}_{\text{CuAu}} = \frac{1 - F^{CuAu}_{B\rightarrow J/\psi}}{1 - F^{pp}_{B\rightarrow J/\psi}} R^{\text{incl.}}_{\text{CuAu}}, \quad R^{B}_{\text{CuAu}} = \frac{F^{CuAu}_{B\rightarrow J/\psi}}{F^{pp}_{B\rightarrow J/\psi}} R^{\text{incl.}}_{\text{CuAu}}$$

Flat detector acceptance in small p_T region.

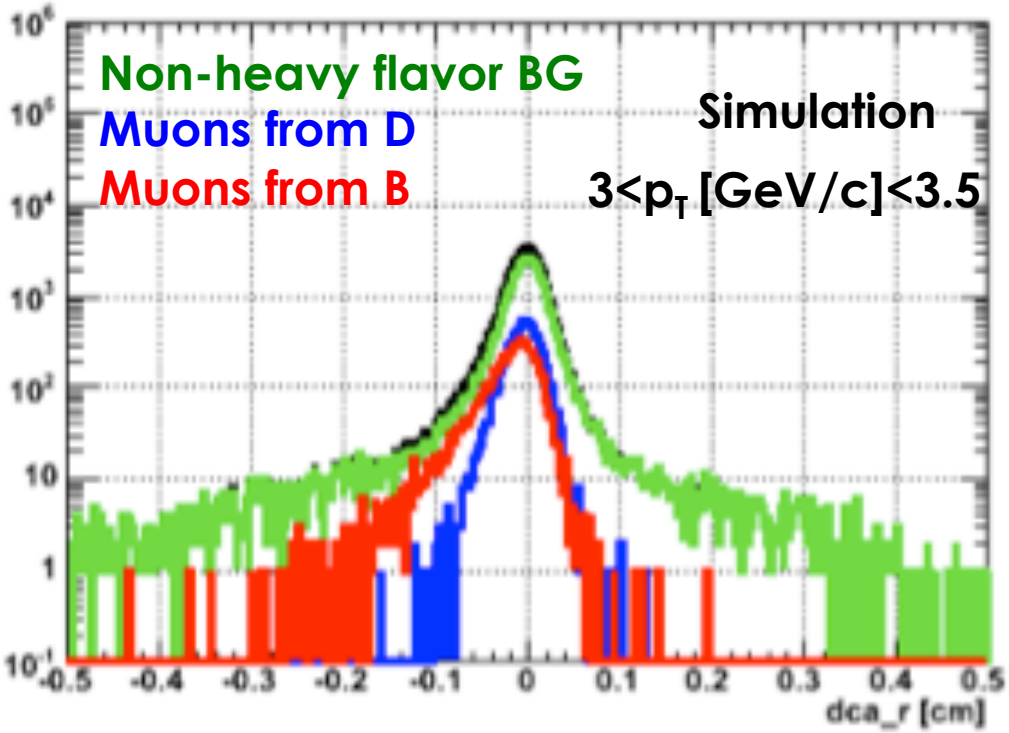
Clean access to small p_T B-mesons.

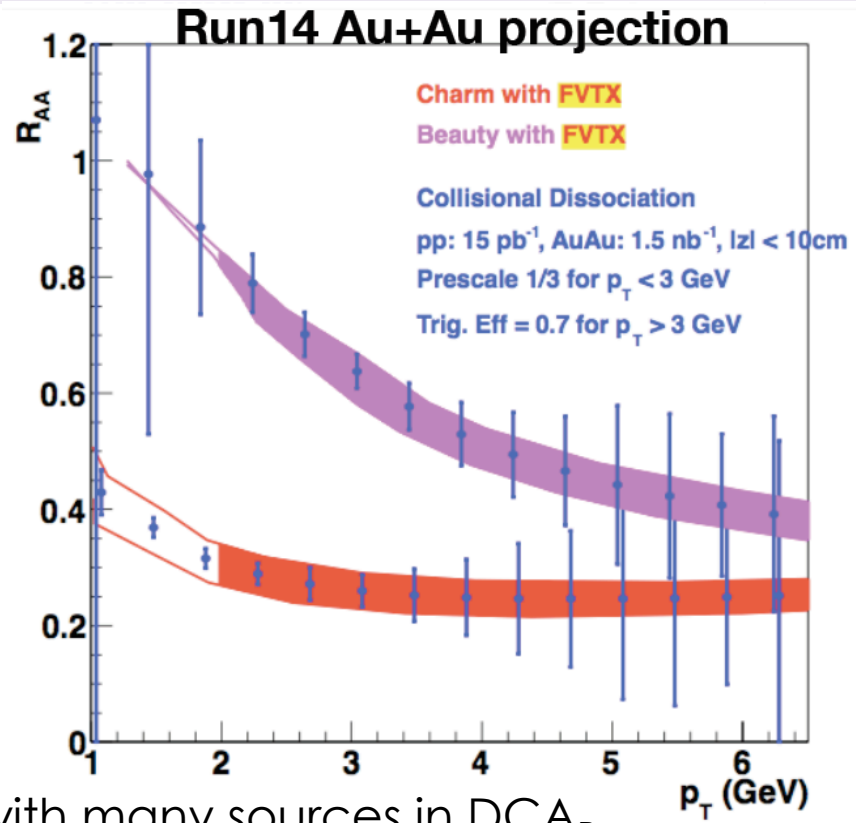
Boosted B-mesons :

- longer decay length
- may also have physics implications on path length until hadronization



Charm and Bottom from inclusive single muons





- Provides high statistics but needs to deal with many sources in DCA_R distribution.
- Very careful analysis underway with Cu+Au and p+p data sets to minimize systematics.

Opportunity in many data samples for R_{AA} and flow measurements.